



HAZARDS OF AMMONIA RELEASES AT AMMONIA REFRIGERATION FACILITIES

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment. EPA is striving to learn the causes and contributing factors associated with chemical accidents and to prevent their recurrence. Major chemical accidents cannot be prevented solely through command and control regulatory requirements, but by understanding the fundamental root causes, widely disseminating the lessons learned, and integrating these lessons learned into safe operations. EPA will publish *Alerts* to increase awareness of possible hazards. It is important that personnel who operate refrigeration systems, managers of facilities, SERCs, LEPCs, emergency responders and others review this information and take appropriate steps to minimize risk.

PROBLEM

Anhydrous ammonia is used as a refrigerant in mechanical compression systems at a large number of industrial facilities. Ammonia is a toxic gas under ambient conditions. Many parts of a refrigeration system contain ammonia liquefied under pressure. Releases of ammonia have the potential for harmful effects on workers and the public; if the ammonia is under pressure, larger quantities may be released rapidly into the air. Also, some explosions have been attributed to releases of ammonia contaminated with lubricating oil. This *Alert* further discusses these potential hazards and the steps that can be taken to minimize risks. This *Alert* should be reviewed by personnel who operate and maintain refrigeration systems, managers of facilities, and emergency responders (e.g., haz mat teams).

ACCIDENTS

A number of accidental releases of ammonia have occurred from refrigeration facilities in the past. Causes of these releases include plant upsets, leading to the

lifting of relief valves; leaks in rotating seals; pipeline failures; vehicular traffic hitting pipes, valves, and evaporators; and failures during ammonia delivery, such as hose leaks. Some of these releases have killed and injured workers, caused injuries off site, or resulted in evacuations. The following describes several recent incidents in more detail.

A specific incident demonstrates the need for mechanical protection to protect refrigeration equipment from impact. In a 1992 incident at a meat packing plant, a forklift struck and ruptured a pipe carrying ammonia for refrigeration. Workers were evacuated when the leak was detected. A short time later, an explosion occurred that caused extensive damage, including large holes in two sides of the building. The forklift was believed to be the source of ignition. In this incident, physical barriers would have provided mechanical protection to the refrigeration system and prevented a release.

Another incident highlights the need for an adequate preventive maintenance program and scheduling. In a 1996 incident in a produce cold storage facility, oil pressure got low

CHEMICAL SAFETY

ALERT

over a long weekend in an older ammonia refrigeration system. The low oil pressure cutout switch failed and the compressor tore itself apart, resulting in a significant ammonia release. The periodic testing of the low oil pressure cutout switch against a known standard would have prevented this incident.

Two other incidents illustrate the potential for serious effects from accidental releases from ammonia refrigeration systems, although the causes of these releases were not reported. In a 1986 incident in a packing plant slaughterhouse, a refrigeration line ruptured, releasing ammonia. Eight workers were critically injured, suffering respiratory burns from ammonia inhalation, and 17 others were less severely hurt. A 1989 ammonia release in a frozen pizza plant led to the evacuation of nearly all of the 6,500 residents of the town where the plant was located. The release started when an end cap of a 16-inch suction line of the ammonia refrigeration system was knocked off. Up to 45,000 pounds of ammonia was released, forming a cloud 24 city blocks long. About 50 area residents were taken to hospitals, where they were treated with oxygen and released, while dozens of others were treated with oxygen at evacuation centers.

HAZARD AWARENESS

Ammونيا is used widely and in large quantities for a variety of purposes. More than 80% of ammonia produced is used for agricultural purposes; less than two percent is used for refrigeration. Use of ammonia is generally safe provided appropriate maintenance and operating controls are exercised. It is important to recognize, however, that ammonia is toxic and can be a hazard to human health. It may be harmful if inhaled at high concentrations. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Level (PEL) is 50 parts per million (ppm), 8-hour time-weighted average. Effects of inhalation of ammonia range from irritation to severe respiratory injuries, with possible fatality at higher concentrations. The National Institute of Occupational Safety and Health (NIOSH) has established an Immediately Dangerous to Life and Health (IDLH) level of 300 ppm for the purposes of respirator selection. Ammonia is corrosive and can burn the skin and eyes. Liquefied ammonia can cause frostbite.

The American Industrial Hygiene Association (AIHA) has developed Emergency Response Planning Guidelines (ERPGs) for a number of substances to assist in planning for catastrophic releases to the community. The ERPG-2 represents the concentration below which it is believed nearly all individuals could be exposed for up to one hour without irreversible or serious health effects. The ERPG-2 for ammonia is 200 ppm. EPA has adopted the ERPG-2 as the toxic endpoint for ammonia for the offsite consequence analysis required by the Risk Management Program (RMP) Rule under section 112(r) of the Clean Air Act.

In refrigeration systems, ammonia is liquefied under pressure. Liquid ammonia that is accidentally released may aerosolize (i.e., small liquid droplets may be released along with ammonia gas) and behave as a dense gas, even though it is normally lighter than air (i.e., it may travel along the ground instead of immediately rising into the air). This behavior may increase the potential for exposure of workers and the public.

Although pure ammonia vapors are not flammable at concentrations of less than 16%, they may be a fire and explosion hazard at concentrations between 16 and 25%. Mixtures involving ammonia contaminated with lubricating oil from the system, however, may have a much broader explosive range. A study conducted to determine the influence of oil on the flammability limits of ammonia found that oil reduced the lower flammability limit as low as 8%, depending on the type and concentration of oil (Fenton, et al., 1995).

An important property of ammonia is its pungent odor. Odor threshold varies with the individual but ammonia can be usually detected at concentrations in the range of about 5 ppm to 50 ppm. Concentrations above about 100 ppm are uncomfortable to most people; concentrations in the range of 300 to 500 ppm will cause people to leave the area immediately.

HAZARD REDUCTION

The Chemical Accident Prevention Group of EPA's Region III (Pennsylvania, Maryland, Virginia, West Virginia, Delaware, and the District of Columbia) has been evaluating facilities in Region III with ammonia refrigeration systems to gather information on safety practices and

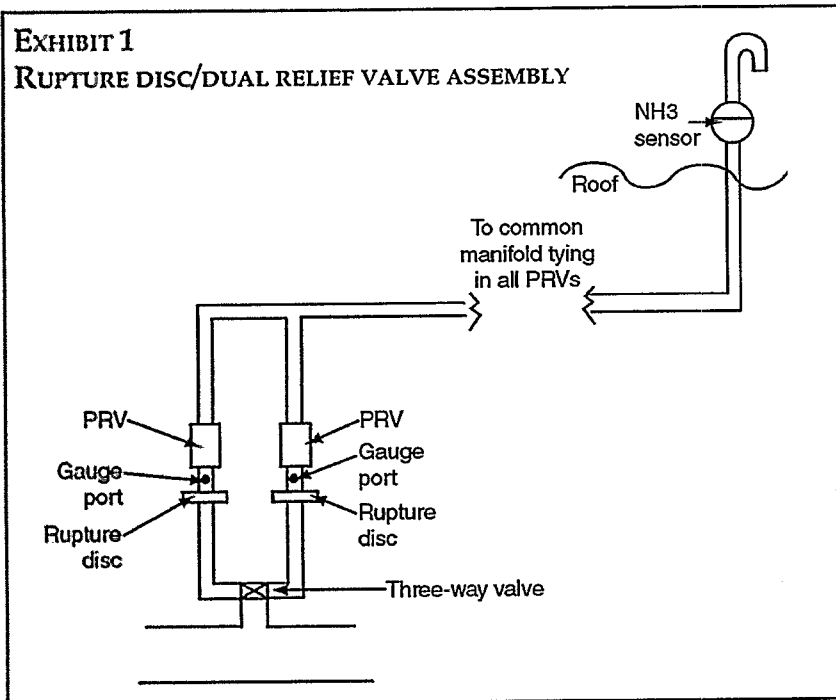
technologies and to share its knowledge with these facilities. Region III has conducted more than 120 audits from 1995 to the present of both large and small facilities using ammonia for refrigeration. To share their findings from the audits, including both the deficiencies observed and the actions that facilities are taking to increase safety, Region III has made presentations to the Refrigerating Engineers and Technicians Association (RETA). This *Alert* is intended to communicate these findings to a wider audience.

Ammonia refrigeration facilities should be aware of the potential hazards of ammonia releases and of the steps that can be taken to prevent such releases. They should be prepared to respond appropriately if releases do occur. Here are steps that ammonia refrigeration facilities could take to prevent releases and reduce the severity of releases that do occur include:

- Establish training programs to ensure that the ammonia refrigeration system is operated and maintained by knowledgeable personnel.
- Consider using a spring-loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out pots (used to collect oil that leaks through seals) as an "emergency stop valve."
- Develop written standard operating procedures for removing oil from the oil out pots. Consider developing an in-house checklist to guide mechanics through the procedure.
- Remove refrigeration oil from the refrigeration system on a regular basis. Never remove oil directly from the refrigeration system without pumping down and properly isolating that component.
- Provide barriers to protect refrigeration equipment, i.e., lines, valves, and refrigeration coils, from impact in areas where forklifts are used. Consider starting a forklift driver training program.
- Develop and maintain a written preventive maintenance program and schedule based on the manufacturer's recommendations for all of the refrigeration equipment. The preventive maintenance program should include, but not be limited to:
 - a) compressors
 - b) pumps
 - c) evaporators
 - d) condensers
 - e) control valves
 - f) all electrical safety(s), including
 - 1) high pressure cutouts
 - 2) high temperature cutouts
 - 3) low pressure cutouts
 - 4) low temperature cutouts
 - 5) low oil pressure cutouts
 - g) ammonia detectors
 - h) emergency response equipment, including
 - 1) air monitoring equipment
 - 2) self-contained breathing apparatus (SCBA)
 - 3) level A suit
 - 4) air-purifying respirators
- Perform vibration testing on compressors. Document and analyze results for trends.
- Maintain a leak-free ammonia refrigeration system. Investigate all reports of an ammonia odor and repair all leaks immediately. Leak test all piping, valves, seals, flanges, etc., at least four times a year. Some methods which can be used for leak testing are sulfur sticks, litmus paper, or a portable monitor equipped with a flexible probe.
- Consider installing ammonia detectors in areas where a substantial leak could occur or if the facility is not manned 24 hours/day. The ammonia detectors should be monitored by a local alarm company or tied into a call-down system. Ensure that the ammonia detectors are calibrated regularly against a known standard. Check the operation of ammonia sensors and alarms regularly.
- Replace pressure relief valves (PRVs) on a five-year schedule; document replacement dates by stamping the replacement date onto each unit's tag.
- Replace single PRVs with dual relief valves. A dual relief valve installation consists of one three-way dual shut-off valve with two pressure safety relief valves.
- For large systems with many PRVs, consider using the arrangement shown in Exhibit 1 for detecting leakage. This arrangement includes installation of a rupture disc upstream of each PRV with a gauge port or transducer in between the disc and PRV and installation of an

ammonia sensor in the PRV common manifold. In case of leakage from a PRV, the sensor would set off an alarm. A check of either the pressure gauge or transducer signal would permit easy identification of which PRV has popped.

EXHIBIT 1
RUPTURE DISC/DUAL RELIEF VALVE ASSEMBLY



- Consider installing a low water level probe with an alarm in the water sump for the evaporative condenser(s) to warn of water supply failure.
- Ensure that the ammonia refrigeration system is routinely monitored. Consider using a daily engine room log, recording process parameters (e.g., temperature and pressure levels) and reviewing the log on a regular basis. Consider having the chief engineer and the refrigeration technician sign the daily engine room log. In designing new systems or retrofitting existing systems, consider the use of computer controls to monitor the process parameters.
- Keep an accurate record of the amount of ammonia that is purchased for the initial charge to the refrigeration system(s) and the amount that is replaced. Consider keeping a record of the amount of lubricating oil added to the system and removed from the system.
- Ensure that good housekeeping procedures are followed in the compressor rooms.
- Ensure that refrigeration system lines and valves are adequately identified (e.g., by color coding or labeling) by using an in-house system.
- Properly post ammonia placards (i.e. NFPA 704 NH₃ diamond) and warning signs in areas where ammonia is being used as a refrigerant or being stored (for example, compressor room doors). Properly identify the chemicals within the piping system(s); label all process piping, i.e. piping containing ammonia, as "AMMONIA." Label must use black letters with yellow background. (This requirement is not the same as the in-house color coding system.)
 - Periodically inspect all ammonia refrigeration piping for failed insulation/vapor barrier, rust, and corrosion. Inspect any ammonia refrigeration piping underneath any failed insulation systems for rust and corrosion. Replace all deteriorated refrigeration piping as needed. Protect all un-insulated refrigeration piping from rust and/or corrosion by cleaning, priming, and painting with an appropriate coating.
- Carry out regular inspections of emergency equipment and keep respirators, including air-purifying and self-contained breathing apparatus (SCBA), and other equipment in good shape; ensure that personnel are trained in proper use of this equipment. For SCBA, it is important to ensure that air is bone dry. For air-purifying respirators, replace cartridges as needed and check expiration dates.
- Consider using the compressor room ammonia detector to control the ventilation fans.
- Identify the king valve and other emergency isolation valves with a large placard so that they can easily be identified by emergency responders, in case of an emergency. These valves should be clearly indicated on the piping and instrumentation diagrams (P&IDs) and/or process flow diagrams.
- Establish emergency shutdown procedures and instructions on what to do during and after a power failure.

- Establish written emergency procedures and instructions on what to do in the event of an ammonia release.
- Mount a compressor room ventilation fan manual switch outside of the compressor room and identify it with a placard for use in an emergency. Good practice would be to have ventilation switches located outside and inside of each door to the compressor room.
- Mount windsocks in appropriate places and incorporate their use into the facility emergency response plan. In addition to the emergency response plan, consider developing additional materials (posters, signs, etc.) to provide useful information to employees and emergency responders in case of an emergency.
- Keep piping and instrumentation diagrams (P&IDs), process flow diagrams, ladder diagrams, or single lines up-to-date and incorporate them into training programs for operators.
- Stage a realistic emergency response spill exercise with the local fire company.

References

Fenton, D.L., K.S. Chapman, R.D. Kelley, and A.S. Khan. 1995. Operating Characteristics of a flare/oxidizer for the disposal of ammonia from an industrial refrigeration facility. *ASHRAE Transactions*, 101 (2), pp. 463-475. Atlanta, GA: American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

INFORMATION RESOURCES

General References

The Alaska DEC fact sheet on preventing accidental releases of anhydrous ammonia is available at: <http://es.inel.gov/techinfo/facts/alaska/ak-fs03.html>



CEPPO has prepared a general advisory on ammonia (OSWER 91-008.2 Series 8 No. 2), available at: <http://www.epa.gov/ceppo/acc-his.html>.

Statutes and Regulations

The following are a list of federal statutes and regulations related to process safety, accident prevention, emergency planning, and release reporting.

EPA

Clean Air Act (CAA)

- General Duty Clause [Section 112(r) of the Act]- Facilities have a general duty to prevent and mitigate accidental releases of extremely hazardous substances, including ammonia.
- Risk Management Program (RMP) Rule [40 CFR 68]- Facilities that have anhydrous ammonia in quantities greater than 10,000 pounds are required to develop a hazard assessment, a prevention program, and an emergency response program. EPA has developed a model guidance to assist ammonia refrigeration facilities comply with the RMP rule.

Emergency Planning and Community Right-to-Know (EPCRA)

- Emergency Planning [40 CFR Part 355]- Facilities that have ammonia at or above 500 pounds must report to their LEPC and SERC and comply with certain requirements for emergency planning.
- Emergency Release Notification [40 CFR Part 355]- Facilities that release 100 pounds or more of ammonia must immediately report the release to the LEPC and the SERC.
- Hazardous Chemical Reporting [40 CFR Part 370]- Facilities that have ammonia at or above 500 pounds must submit a MSDS to their LEPC, SERC, and local fire department and comply with the Tier I/ Tier II inventory reporting requirements.
- Toxic Chemicals Release Inventory [40 CFR Part 372]- Manufacturing businesses with ten or more employees that manufacture, process, or otherwise use ammonia above an applicable threshold must file annually a Toxic Chemical Release form with EPA and the state.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

- Hazardous Substance Release Reporting [40 CFR Part 302]- Facilities must report to the National Response Center (NRC) any

environmental release of ammonia which exceeds 100 pounds. A release may trigger a response by EPA, or by one or more Federal or State emergency response authorities.



OSHA

- **Process Safety Management (PSM) Standard** [29 CFR 1910] Ammonia (anhydrous) is listed as a highly hazardous substance. Facilities that have ammonia in quantities at or above the threshold quantity of 10,000 pounds are subject to a number of requirements for management of hazards, including performing a process hazards analysis and maintaining mechanical integrity of equipment.
- **Hazard Communication** [29 CFR 1910.1200] - Requires that the potential hazards of toxic and hazardous chemicals be evaluated and that employers transmit this information to their employees.

For additional information, contact OSHA Public Information at (202) 219-8151.

Web site: <http://www.osha.gov>

Codes and Standards

There are a number of American National Standards Institute (ANSI) Standards available for refrigeration systems. Some examples are given below.

ANSI/ASHRAE Standard 15-1994 - Safety Code for Mechanical Refrigeration

Available for purchase from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) International Headquarters, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. Customer service: 1-800-527-4723

ANSI/IIAR 2-1992 - Equipment, Design, and Installation of Ammonia Mechanical Refrigeration Systems

Available from the International Institute of Ammonia Refrigeration (IIAR)
1200 19th Street, NW
Suite 300
Washington, DC 22036-2422
(202) 857-1110

Web site: <http://www.iiar.org>

ISO 5149-1993 - Mechanical Refrigerating Systems Used for Cooling and Heating -- Safety Requirements

Available from the American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
(212) 642-4900

Web site: <http://www.ansi.org>

FOR MORE INFORMATION...

CONTACT THE EMERGENCY PLANNING AND
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(800) 424-9346 OR (703) 412-9810
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